

HIGH PHENOTYPIC FREQUENCIES OF COMPLETE ALBINISM
IN WILD POPULATIONS OF *BIOMPHALARIA PFEIFFERI*
(GASTROPODA: PULMONATA)

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Complete albinism in wild animal populations is a rare condition. It is characterized by the lack of melanin in both the integument and eyes. Consequently, there are few reports on this type of albinism. The phenotypic frequency ranges from 0.00007 to 0.0002 in humans (Africans) (Hong et al., 2006) and is 0.002 in the cave-dwelling bat, *Hipposideros diadema nicobarensis* (Aul & Marimuthu, 2006). In amphibians, frequency ranges from 0.02 to 0.03 in the cavern salamander *Gyrinophilus porphyriticus* (Brandon & Rutherford, 1967), and is the highest (0.12) in the chorus frog *Pseudacris triseriata* (Corn, 1986).

In wild populations of freshwater snails, complete albinism has been observed, but its frequency has been recorded only rarely. Yusa (2004) collected 2,000 snails of *Pomacea canaliculata* in lotus fields and adjacent canals in Kumamoto, Japan, and found that 28 (1.4%) were albino (yellow). The frequency (0.014) of this phenotype remained constant for six years in the collection area. Madsen et al. (1983) reported the existence of “a few” albinos in *Helisoma duryi* during a malacological survey in Bamburi, Kenya. Dillon & Wethington (1992) found one *Biomphalaria obstructa* and two *Physa heterostroph*a albino snails “among thousands of individuals” collected in South Carolina.

Researchers who have used albino strains of freshwater snails for genetic crossing experiments with melanic strains or for host-parasite compatibility studies have only reported the origin of the albino strain, such as Richards (1962) for *Biomphalaria glabrata* from Venezuela, Boissier & Moné (2001), and Boissier et al. (2003) for *B. glabrata* from Brazil, Rosa et al. (2004) for *Biomphalaria tenagophila* from Brazil, and Davis & Ruff (1973) for *On-*

comelania hupensis from southern Taiwan. Most genetic studies using albino snails have been performed with albino individuals that originated as “spontaneous mutations” from laboratory-maintained snail colonies. These animals were then isolated and established for experimental purposes. The well-known albino strain of *B. glabrata* that originated in the laboratory of Newton (1954, 1955) has been used for numerous studies. This strain has been used widely for genetic analyses (Richards, 1969, 1973) and for genetic studies on compatibility with *Schistosoma mansoni* (Richards & Merritt, 1972; Mulvey & Woodruff, 1985), the causative agent of human intestinal bilharziasis. Other laboratory-discovered albino snails include *Lymnaea peregra* (Boycott & Diver, 1927) and *Oncomelania formosana* (Moose & Suzuki, 1964).

The present paper is on the phenotypic frequencies of complete albinism in wild populations of *Biomphalaria pfeifferi* (Fig. 1), the intermediate host of *S. mansoni* in Africa and the Middle-East (Dejong et al., 2003). The relationship between the condition of albinism and several environmental factors related to water quality were tested.

This study was done in the Dhofar region in southwestern Oman near Yemen (Fig. 2) where bilharziasis is reemerging (Idris et al., 2003; Moné et al., 2003). The area of study forms a wide band 250 km long and 30 km wide (7,500 km²) along the Dhofar coast and includes three drainage basins that empty into the Arabian Sea (Figs. 3–5). Fourteen sites harboring *B. pfeifferi* were surveyed for the snails nine times between November 2000 and November 2007 (Figs. 3–5). These sites are situated in spring-fed rivers, and most of them are isolated from each other without any

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confluence in the valleys (Table 1). They were surveyed at least three times.

Snails were collected with a stainless steel strainer (18 cm in diameter, 8 cm deep, 20 cm handle, and 1 mm pore size) attached to a wooden handle 140 cm long. The snails were transported to the laboratory in Salalah for identification using anatomical features (Ibikounlé et al., 2008). The frequencies of albinism were determined at the time of each survey. The GPS position (longitude and latitude) and altitude of each site were determined (Table 1). Water quality at these sites was defined once in May 2007 by eight parameters: temperature (°C), oxygen (mg/L), pH, nitrite (mg/L), nitrate (mg/L), ammonium (mg/L), phosphate (mg/L) and total hardness (mg/L) using Compact Laboratory Merck KGaA (64271 Darmstadt, Germany). All the data are recorded in Table 1. A principal component analysis centred and standardized was

performed using R version 2.4.0 software. The non-parametric Kruskal-Wallis test was performed on the environmental data using SPSS version 10.0.5 software.

The total number of *B. pfeifferi* snails collected in the study was 16,613. Albino snails were found in only two out of the 14 sites: in Siginitti, from May 2001 onwards, and in Tibraq only in May 2007 (Table 2). These two sites are isolated from each other (Fig. 4). The principal component analysis showed that none of the environmental parameters was associated with the presence of albinism. The first and second axes explained only 24.8 and 20.6% of variance, respectively. There was no significant difference in the environmental parameters ($P > 0.05$) between the two sites harbouring albino snails and the other 12 sites.

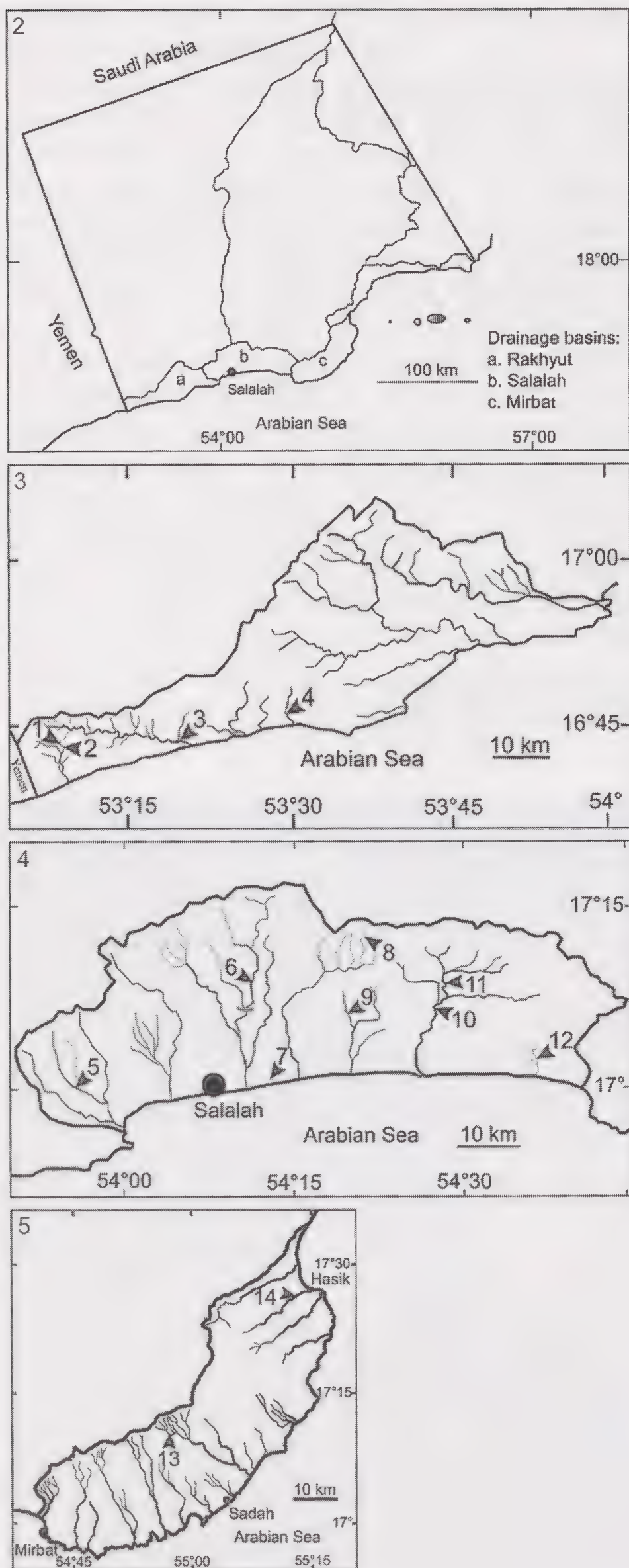
In both Siginitti and Tibraq, albino and melanic snails coexist and are exposed to



FIG. 1. Albino and pigmented *Biomphalaria pfeifferi* feeding on a fig in natural conditions in Dhofar (Oman). Scale bar = 8 mm.

TABLE 1. Name, longitude, latitude, altitude, and eight water testing parameters of the surveyed sites harbouring *Biomphalaria pfeifferi* in Dhofar, Oman. *, ** and *** show the sites that are situated in the same valley. In bold, the two sites harbouring albino snails.

Name	Longitude (East)	Latitude (North)	Altitude (m)	Temperature (°C)	O ₂ (mg/L)	pH	Nitrite (mg/L)	Nitrate (mg/L)	Ammonium (mg/L)	Phosphate (mg/L)	Total Hardness (mg/L)
Sarfait*	53°08'13.99"	16°41'47.69"	636	27	9.1	8.00	0.025	10	0.00	0.00	570
Kohood*	53°08'14.83"	16°42'17.99"	818	30	6.6	7.50	0.050	10	0.00	0.00	350
Kharfut	53°19'41.43"	16°44'02.84"	41	31	13.2	7.50	0.000	10	0.50	0.00	380
Hotah	53°30'44.71"	16°45'50.37"	57	31	9.9	8.00	0.000	0	0.00	0.00	370
Sheitt	53°49'06.54"	17°00'01.47"	221	31	6.2	8.00	0.000	0	0.00	0.15	370
Sahalnout	54°10'43.02"	17°08'53.64"	200	32	8.4	7.50	0.000	10	0.00	0.00	315
Arazat farm**	54°12'58.86"	17°02'14.09"	22	30	9.1	8.25	0.200	0	0.15	0.00	230
Birin**	54°19'37.31"	17°13'35.94"	793	27	11.4	8.25	0.500	50	0.20	0.10	350
Tibraq	54°19'35.09"	17°05'58.11"	101	29	16.3	8.00	0.025	10	0.00	0.00	280
Wadi Derbat***	54°27'12.09"	17°06'12.57"	201	36	10.0	8.00	0.060	10	0.00	0.00	310
Siginitti***	54°28'08.99"	17°08'36.44"	334	29	10.3	7.50	0.500	10	0.00	0.10	370
Heisher	54°36'29.17"	17°03'14.58"	286	31	9.7	8.00	0.000	0	0.00	0.00	350
Lagga-Shalyun	54°56'29.12"	17°11'20.34"	467	29	7.6	8.50	0.000	0	0.50	0.10	265
Had Barm	55°14'36.42"	17°26'32.14"	33	26	6.5	7.50	0.000	0	0.00	0.00	520



FIGS. 2–5. Maps of Dhofar Governorate. FIG. 2: General view of the three drainage basins (a: Rakhyut basin, see Fig. 3; b: Salalah basin, see Fig. 4; c: Mirbat basin, see Fig. 5); FIGS. 3–5: Exact positions (arrows with numbers) of each of the 14 surveyed points in each of these three drainage basins. 1: Sarfait; 2: Kohood; 3: Kharfut; 4: Hotah; 5: Sheitt; 6: Sahalnout; 7: Arazat farm; 8: Birin; 9: Tibraq; 10: Wadi Derbat; 11: Siginitti; 12: Heisher; 13: Lagga-Shalyyun; 14: Had Barm.

the same environmental conditions, such as water velocity, flooding events, temperature, and photoperiod. In Siginitti, albinos were found in 2001 at a frequency of 0.079 and then increased to 0.412 in 2005 and to 0.491 in 2006 (Table 2). In 2007, the frequency increased slightly to 0.494 in May and then dropped significantly to 0.184 in November. In 2003 and 2004 surveys were not possible at Siginitti because a flood in May 2002 washed away the only accessible road to the study site. In Tibraq, albinos were found in May 2007 at the frequency of 0.075 but were no longer present five months later (Table 2). The frequency of the albino allele was inferred for each survey using the observed phenotypic frequencies and the lowest known value of selfing rate for *B. pfeifferi*, 0.787 (Charbonnel et al., 2002). The calculated values of albino allelic frequencies are slightly higher than the observed frequencies presented (Table 2).

This is the first report of the presence of albinism in wild populations of *B. pfeifferi*. The observed phenotypic frequencies close to 0.50 are the highest ever recorded for wild populations of snails. Prior to this study, the highest frequency of 0.12 was found in the frog *P. triseriata* in which the survival rate of the embryos and growth of the juveniles was the same as the melanic phenotype (Corn, 1986).

We found that albino snails in the wild can be present at high frequencies (> 0.40) for extended periods of up to 20 months. With a generation time of three months, this represents about six reproductive cycles. In this study, the condition of albinism could not be correlated to water quality as defined by measurements of 8 parameters. In order to understand the causes of temporal variations in the phenotypic frequencies of albinism, the effects of genetic drift, migration and natural selection need to be evaluated.

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TABLE 2. Observed phenotypic (Obs. F) and expected (estimated) allelic (Exp. F) frequencies of complete albinism in *Biomphalaria pfeifferi* in Siginitti and Tibraq sites (Dhofar, Oman); n = number of snails collected.

Month, Year	Siginitti			Tibraq		
	Obs. F	Exp. F	n	Obs. F	Exp. F	n
November 2000	0.000	0.000	453	0.000	0.000	89
May 2001	0.079	0.114	229	0.000	0.000	664
February 2002	0.051	0.075	474	0.000	0.000	553
September 2002	-	-	-	0.000	0.000	150
December 2003/January 2004	-	-	-	0.000	0.000	667
September 2005	0.412	0.500	578	0.000	0.000	328
February 2006	0.491	0.577	407	0.000	0.000	51
May 2007	0.494	0.580	162	0.075	0.110	623
November 2007	0.184	0.250	620	0.000	0.000	272

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